Matched filter detection of foreshocks in a large-scale friction experiment

*Ryo Ishiyama[1], Bogdan Enescu[1,2], Eiichi Fukuyama[3,4], Futoshi Yamashita[4]

1. Department of Geophysics, Kyoto University, 2. National Institute for Earth Physics, 3. Department of Civil and Earth Resources Engeneering, Kyoto University , 4. National Research Institute for Earth Science and Disaster Resilience

The foreshock activity prior to a large earthquake is closely related to the mainshock generation process (e.g., Shimojo et al., 2021) and is at present a topic of active research. Laboratory experiments and numerical models can help understand the mechanism of foreshock occurrence leading to the mainshock. For example, Yamashita et al. (2021) used a STA/LTA (ratio of absolute amplitudes between a short-time-average and a long-time-average window) signal detection technique and catalogued more than 1000 foreshocks generated in a large-scale rock friction experiment to reveal the migration pattern of foreshock activity and relate it to the physical properties of laboratory faults. As such studies suggest, the foreshock activity can help us understand the ongoing physical processes that take place on a fault. To investigate the underlying mechanisms in detail, it is important to detect and locate as many events as possible. However, the foreshock waveforms are complex and rather difficult to distinguish by the human eye since many of them may occur in a short period of time and may also overlap one with each other on the continuous waveform records. This study aims to detect as many of these lab events as possible by using the Matched Filter Technique (MFT) (e.g., Peng and Zhao, 2009).

We analyzed acoustic emission data observed at 64 acoustic sensors in a large-scale friction experiment (Yamashita et al., 2021). Arbitrary events are first selected from the event catalogue data of Yamashita et al. (2021); we then extract their waveforms (S-wave trains) and use them as templates at the 10 recording stations (i.e., sensors) that are closest to the epicenter of the template event. Further away stations were not used to minimize the effect of noise. The correlation coefficients between the continuous and the template waveforms were then calculated at all 10 stations by shifting the template waveforms along the continuous waveforms with a step of one sample. Finally, the obtained cross-correlation time series were stacked to calculate a mean correlation coefficient.

Applying the method described above to a test dataset with active foreshock activity immediately before a mainshock, the largest mean correlation coefficient (of about 0.5) has been obtained for an event (i.e., detection) that occurred about 1mm away from the template event, according to the catalog of Yamashita et al., (2021). This indicates that we were able to successfully detect a laboratory event, close to the template event, by the MFT method. By using a large number of catalogued events, which occurred at various locations, as templates, and further calibrating the method, we will aim detecting new events (i.e., events that were not catalogued by Yamashita et al., 2021) and analyze the MFT-based acoustic emission catalogue. Results of this on-going investigation will be presented at the meeting.

